

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

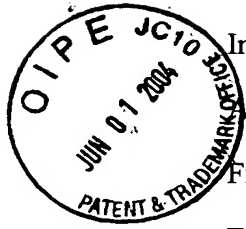
- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

**THIS PAGE BLANK (USPTO)**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE



In re application of: Mervyn John ROSE et al.

Confirmation No.: 7787

Application No: 10/773,696

Group Art Unit: 2812

Filing Date: February 6, 2004

Examiner:

For: FIELD EMISSION BACKPLATE

Atty. Docket No.: 85170-5100

**SUBMISSION OF CERTIFIED PRIORITY DOCUMENTS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, Virginia 22313-1450

Sir:

Applicants have claimed priority under 35 U.S.C. § 119 of Application Nos. GB 0119657.5 and GB 0119659.1, filed August 11, 2001 in Great Britain. In support of this claim, certified copies of said applications are submitted herewith.

No fee or certification is believed to be due for this submission. Should any fees be required, however, please charge such fees to **Winston & Strawn LLP** Deposit Account No. 50-1814.

Respectfully submitted,

Date: 6/1/04

  
Allan A. Fanucci (Reg. No. 30,256)

**WINSTON & STRAWN LLP**  
**CUSTOMER NO. 28765**  
(212) 294-3311

Enclosures

**THIS PAGE BLANK (USPTO)**



INVESTOR IN PEOPLE

The Patent Office  
Concept House  
Cardiff Road  
Newport  
South Wales  
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears a correction, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Dated 9 March 2004

**THIS PAGE BLANK (USPTO)**



1/77

13AUG01 E652336-1 D00239  
P01/7700 0.00-01196571 The Patent Office

## Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

Cardiff Road  
Newport  
South Wales  
NP10 8QQ

1. Your reference

DM/RP/MG/P11228GB

2. Patent application number

(The Patent Office will fill in this part)

0119657.5

11 AUG 2001

3. Full name, address and postcode of the or of each applicant (underline all surnames)

UNIVERSITY OF DUNDEE  
NETHERGATE  
PERTH ROAD  
DUNDEE  
DD1 4HN

The University Court of  
the University of Dundee

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

798207004

ET  
F11/77  
17.6.02

4. Title of the invention

IMPROVED FIELD EMISSION BACKPLATE

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

CRUIKSHANK & FAIRWEATHER  
19 ROYAL EXCHANGE SQUARE  
GLASGOW G1 3AE

Patents ADP number (if you know it)

547002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

Priority application number  
(if you know it)

Date of filing  
(day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
(day / month / year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

- a) any applicant named in part 3 is not an inventor, or
  - b) there is an inventor who is not named as an applicant, or
  - c) any named applicant is a corporate body.
- See note (d))

**Patents Form 1/77**

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description

11 13

Claim(s)

Abstract

Drawing(s)

3+3 18

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)

Request for preliminary examination and search (*Patents Form 9/77*)

Request for substantive examination (*Patents Form 10/77*)

Any other documents  
(please specify)

11. I/We request the grant of a patent on the basis of this application.

Signature

Date

CRUIKSHANK & FAIRWEATHER

10 August 2001

12. Name and daytime telephone number of person to contact in the United Kingdom

Dr. David Moreland - 0141-221-5767

**Warning**

*After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.*

**Notes**

- a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.
- b) Write your answers in capital letters using black ink or you may type them.
- c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.
- d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.
- e) Once you have filled in the form you must remember to sign and date it.
- f) For details of the fee and ways to pay please contact the Patent Office.



IMPROVED FIELD EMISSION BACKPLATE

FIELD OF INVENTION

5           The present invention relates to a field emission backplate for use in a display, to a field emission display and to an associated method of manufacture. In particular the invention relates to a field emission display having a field emission backplate having a plurality of profiled tips formed  
10 by selective growth of crystalline silicon on a locally crystallised area.

BACKGROUND TO INVENTION

15           Flat panel displays are of immense importance in electronics. In current developments Active Matrix Liquid Crystal Displays (AMLCD) are beginning to challenge the dominance of Cathode Ray Tube (CRT) technology. AMLCD devices are non-emissive and require complex lithography. Filters and matching spectral backlights are required to produce colour.  
20 Further, there are many light losses and inherent complexity in AMLCD devices because of the non-linear nature of liquid crystal materials. This results in a display that is less bright than CRT with a smaller colour gamut and poorer viewing angle and contrast. Also, due to the non-emissive nature of  
25 the display, inefficient use of input electrical power is made

often with well over 70% of the energy being lost as non-useful energy.

Field emission displays based on conventional "Spindt Tip" technology, promised a solution to flat panel display problems. Field emission displayed (FEDs) are essentially flat cathode ray tube (CRT) devices. However, rather than one electron gun firing electrons at a phosphor on a screen through a shadow mask, the FED has tens or hundreds of individual tips in each display pixel. The tips are known as Spindt tips, after the inventor Cap Spindt. The process of fabrication relies on defining a pattern of holes in a gate metal by photolithography. An underlying insulator is then etched in an isotropic wet etch that "undercuts" leaving a well beneath the metal. A sacrificial layer, usually nickel is then evaporated on the surface at an oblique angle to ensure the well is not filled. The emitter material, usually tungsten or molybdenum is then evaporated through the holes in the well. As the evaporate metal builds up on the surface, on the sacrificial layer, it closes the hole as the thickness increases, and has the effect of providing an emitter tip in the well. The top metal is then removed by etching the sacrificial layer, leaving the tip, the well and the original gate metal. This forms the back plate of Spindt tips. A top plate containing a patterned phosphor is then placed relative to the backplate using spacers. The final device is evacuated to allow the emitted electrons a long mean free path.

The principle of field emission from micro-tips is governed by Fowler - Nordheim tunneling. The emission current, and therefore brightness of the display, depends then only on the current density, the number of tips and their sharpness, i.e.  $I = J_{FN} n \alpha$ .

Where  $n$  = number of tips,  $\alpha$  the tip sharpness and  $J_{FN}$  the Fowler-Nordheim tunnel current density.

The tips will provide a sharp electron source that will provide hot electron injection into a phosphor.

Unfortunately the extreme complication in fabrication has limited the use of this technology. Additionally crystal silicon emitter are limited by the wafer size.

Other thin-film materials may also be used for field emission. Carbon is the main contender with diamond, diamond like carbon and carbon nano-tubes also suitable. The use of diamond seemed a good choice, however, this is difficult to fabricate and also the mechanism of a supposed negative electron affinity which diamond was claimed to have is now being questioned.

An object of the present invention is to obviate or mitigate at least one of the aforementioned problems.

#### SUMMARY OF INVENTION

According to a first aspect of the present invention there is provided a field emission backplate comprising a plurality

of grown tips, the backplate being made substantially from semiconductor based material.

Preferably the plurality of tips are formed on a thin film of semiconductor based material.

5 It will be understood that in the context of the present invention the term "thin film" is used to define a film of a few nanometers, for example, 1 to 100nm, and typically 10nm.

Preferably the grown tips are "profiled", that is to say grown in a manner resulting in a sharp pointed shape.

10 Conveniently, the tips are grown and etched simultaneously.

Conveniently, the semiconductor based material is silicon or an alloy thereof.

According to a second aspect of the present invention there is provided;

15 a field emission backplate comprising a planar member of substantially amorphous material and a plurality of tips of crystalline material thereon.

Preferably the tips are formed on crystalline areas of the planar member.

20 According to a third aspect of the invention there is provided a field emission backplate comprising a plurality of grown tips, the backplate being made substantially from a thin film silicon based material.

25 Preferably the plurality of tips are formed by the growth of crystalline silicon on plurality of crystallised areas of the thin film of amorphous silicon.

According to a fourth aspect of the invention there is provided a field emission device having a backplate comprising an array of profiled tips formed by the selective growth of crystalline semiconductor based material on a plurality of crystallised areas of a thin film of amorphous semiconductor based material.

Preferably the field emission device is a vacuum device wherein the emitter tips of the backplate act as an emission source in the device.

Conveniently, the field emission device comprises a substrate, a field emitting backplate, an evacuated space and a transparent window, e.g. thin film transparent metal, wherein the field emitting backplate is formed upon the substrate and the evacuated space is located between the field emitting backplate and the thin film transparent metal.

Alternatively, the field emission device further comprises a wide back gap light emitting material, e.g. light emitting polymer into which electrons from the emitter tips of the backplate are emitted.

Conveniently, the field emission device comprises a substrate, a field emitting backplate, on one side of which is formed a plurality of tips, a light emitting polymer and a thin film transparent metal wherein the field emitting backplate is formed upon the substrate, one surface of the light emitting polymer is disposed on the plurality of tips of the light

emitting backplate, the thin film transparent metal be disposed on the other surface of the light emitting polymer.

Conveniently the field emission device is a display device.

5 Preferably, the tips of the field emission backplate of the display device are of a density of at least 100 per square micron.

According to a fifth aspect of the invention there is provided a method of forming a field emission backplate comprising:-  
10

depositing a thin film of amorphous semiconductor based material upon a substrate;

locally crystallising a plurality of areas of the thin film amorphous semiconductor based material; and

15 growing crystalline semiconductor based material upon each of the plurality of crystallised areas of thin film amorphous semiconductor based material.

Conveniently the thin film of amorphous semiconductor based material is deposited on a substrate e.g. by plasma enhanced chemical vapour deposition.  
20

Preferably the plurality of areas of thin film amorphous semiconductor based material are crystallised by exposure to at least one pulse of laser interference pattern.

According to a sixth aspect of the invention there is provided a method of crystallising areas of thin film amorphous  
25

semiconductor based material for use in a field emission backplate comprising:

forming a laser interferometer by splitting and recombining a laser beam;

5 placing the thin film of amorphous semiconductor based material in the plane of recombination of the laser beam;

locally crystallising areas of the thin film of amorphous semiconductor based material by subjecting the thin film to at least one laser pulse, wherein the crystallised areas generated in the thin film amorphous semiconductor based material correspond to the interference pattern of the laser.

10 Preferably, for a backplate of amorphous semiconductor based material wherein the semiconductor based material is hydrogenated amorphous silicon, the laser operates at a wavelength of around 532nm to maximise absorption and preferably the laser is a Nd:YAG laser.

#### BRIEF DESCRIPTION OF DRAWINGS

20 These and other aspects of the invention will become apparent from the following description when taken in combination with the accompanying drawings, which are:-

Figure 1 a representation of a thin film of amorphous silicon onto which is projected a laser interference pattern;

25 Figure 2 a cross-section of a side profile of a grown crystalline silicon backplate according to a first embodiment of the present invention;

Figure 3 a schematic representation of a field emission device having crystalline silicon tips according to a second embodiment of the present invention;

Figure 4 a schematic representation of a field emission device having crystalline silicon tips according to a third embodiment of the present invention; and

Figure 5 a schematic representation of a field emission device having crystalline silicon tips according to a fourth embodiment of the present invention.

#### DETAILED DESCRIPTION OF DRAWINGS

With reference to Figure 1, there is shown a thin film of amorphous silicon disposed upon a substrate of aluminum wherein a pattern of dots cause by laser interference pattern can be seen upon a region of surface of the silicon. The thin film of amorphous silicon is disposed on the substrate of aluminum by plasma enhanced chemical vapour deposition (PECVD). A Nd:YAG pulse laser, having a pulsing duration in the region of 3 to 7 nanoseconds, is used to form an interferometer, with the beam being split and brought back together forming a pattern of dots. The thin film silicon layer is positioned in the plane in which the interference pattern of the laser is formed. The laser interference pattern acts upon the silicon layer creating areas, or dots, of crystallisation. A single pulse of laser the Nd:YAG is used to locally crystallise the region. The laser beam is synchronised with a step and repeat system in the



plane of the thin film silicon forming the laser spots and hence the crystallised dots to be distributed over the entire surface plate of the thin film silicon, thus allow a high density of tips to be made. By using this step and repeat system the plate may be made of any chosen size. An area of 30 $\mu$ m x 30 $\mu$ m is typical for an individual pixel, and hence a micro tip density of 300 x 300 which equals  $9 \times 10^4$  per Red Green Blue (RGB) pixel will be achieved. Such density of emitters is of crucial importance as the emission current of a field emitting device depends on the number of tips and their sharpness.

A selective etch and growth process involving a dilute silane/hydrogen plasma is known to form micro crystalline silicon by allowing strained bonds within a silicon array, to be broken by the mobile hydrogen while deposited silicon atoms form thermodynamically stable crystalline sites. To form emitter tips upon the laser treated thin film silicon of Figure 1 the thin film silicon is subjected to a dilute silane/hydrogen plasma in a reactor. This process is applied to the PECVD deposited thin film silicon which has been laser treated wherein deposition of silicon atoms will only take place on a crystalline substrate therefore upon the crystallised dots of the thin film silicon. Amorphous or weak bonded areas of the structure are simultaneously etched. Continued growth has the effect of profiling the edges of the growing film where the etching effect is more dramatic. As, in

the arrangement of the present invention, the crystalline area is limited in size to less than 100nm, the aspect ratio is such that the edges converge. Therefore, each circular dot of 100nm or less of the emitter plate therefore effectively grows a profile tip. A cross section of the tips grown is shown in Figure 2. It is this profiling that leads to field enhancement of the emitter plate which therefore gives a low threshold (of around 15v/ $\mu$ m) for field emission and thus higher emitter current (i.e. in excess of  $10^{-5}$  amps). The growth and etching processes are mediated by mobile hydrogen and the aspect ratio profiling etching leading to sharp tips over the entire growing surface of the plate of thin film silicon.

Also shown in Figure 2 are spacers which have been formed by using the pulsed laser to rest certain areas of the thin film silicon to create line or dot crystalline structure that have dimensions much bigger than those of the emitter dots. This results in a thicker deposited film being formed upon these crystalline areas. Thus spacers are grown at the time as the emitter tips, allowing placement of gates for three terminal devices.

As the emission current, and therefore the brightness of the display depends upon the current density, the number of tips, and their sharpness, according to  $I = J_{FN} n \propto$  the tips provide a sharp electron source that will provide hot electron injection into the light emitting layer of the device either through an evacuated space or into a wide band gap light

emitting material. The electron gains energy from the applied field, that is the field which is applied across the aluminum acts as an electrode.

5 A field emitting device configuration having crystallised silicon emitter tips formed as described with reference to Figures 1 and 2 is shown in Figure 3. The field emitting device is a vacuum device having grown spacers on the micron scale. The substrate is formed of aluminium onto which the thin film semiconductor based material, in this case thin film hydrogenated amorphous silicon, is disposed by PECVD. As has been detailed previously, a plurality of areas of the hydrogenated amorphous silicon is crystallised by a laser interferometer and, using the growth and etch system, tips and spacers are grown. A plate of patterned Indium Tin Oxide (ITO), disposed on a glass substrate, is arranged to sit on the grown spacers of the emitter backplate. The area between the emitter tips and the ITO is evacuated. The device may further be built into a triode configuration by the deposition of an insulator with a metal gate placed above.

20 A first alternative field emitting device is shown in Figure 4. In this configuration a field emitting device is arranged with a wide band-gap light emitting material, such as a polymer, disposed on top of the field emitting tips for use as the light emitting medium. A diode configuration is fabricated with a thin film transparent metal such as Indium Tin Oxide (ITO). The device has the field emitting backplate

25

of silicon and is formed on a substrate such as aluminium. A plate of patterned ITO on a glass substrate will have a thin film, in the order of many microns, of wide band gap light emitting polymer disposed upon it by, for example, screen printing. The light emitting polymer is then pressed onto the crystalline silicon tips of the backplane. A Al,-Si-polymer-ITO diode structure is thus formed with the polymer of the arrangement being cured upon baking the device to a temperature of approximately 100°C.

A second alternative field emitting device including a metal coated phosphor layer member is shown in Figure 5. The other embodiments may similarly include a phosphorescent layer (not shown).

Such devices are suitable for many display applications having low power consumption and being relatively simple to fabricate. The devices may also be used as the cathodes for high power transistors for microwave amplifiers in the satellite and mobile communication markets.

Various modifications may be made to the invention as hereinbefore described without departing from the scope of the invention. For example, during the laser treatment of the thin film a amorphous silicon the use of a single laser pulse has been described in locally crystallising the region, however, a number of pulses may alternatively be used thus allowing energies as low as  $20\text{mJcm}^{-2}$  to be used. Additionally, it has been described how the crystallisation of larger line or

dot structures can be used to grow spacers during the selective etch and growth process of the tips, however, silicon can also be grown in blocks on an insulator and thin film transistor devices for active address delineated in the same process.

5 The process of crystallising the thin film amorphous silicon has been described by being performed by a pulsed laser, however, this may also be performed by other means such as intense electron beam irradiation or high energy ion beam/particle impact or even thermal annealing. The

10 depositing of the thin film of amorphous silicon which may be intrinsic or doped n-type has been described by plasma enhanced chemical vapour deposition. However, the thin film may also be deposited by sputtering, evaporation or other such means. The substrates on which the thin film silicon has been deposited

15 has been described as aluminum, however, may alternatively be metal such as molybdenum, chromium, or similar. Also in the example given in the description a Nd:YAG laser having 532nm wavelength is used to maximise absorption in silicon, however, other wavelengths can be used and in particular other  
20 wavelengths to maximise absorption in other appropriate semiconductor based materials can be used. The use of a transparent metal to form a diode configuration emitted device in the field is described, however, a suitable conducting polymer may alternatively be used.

**THIS PAGE BLANK (USPTO)**

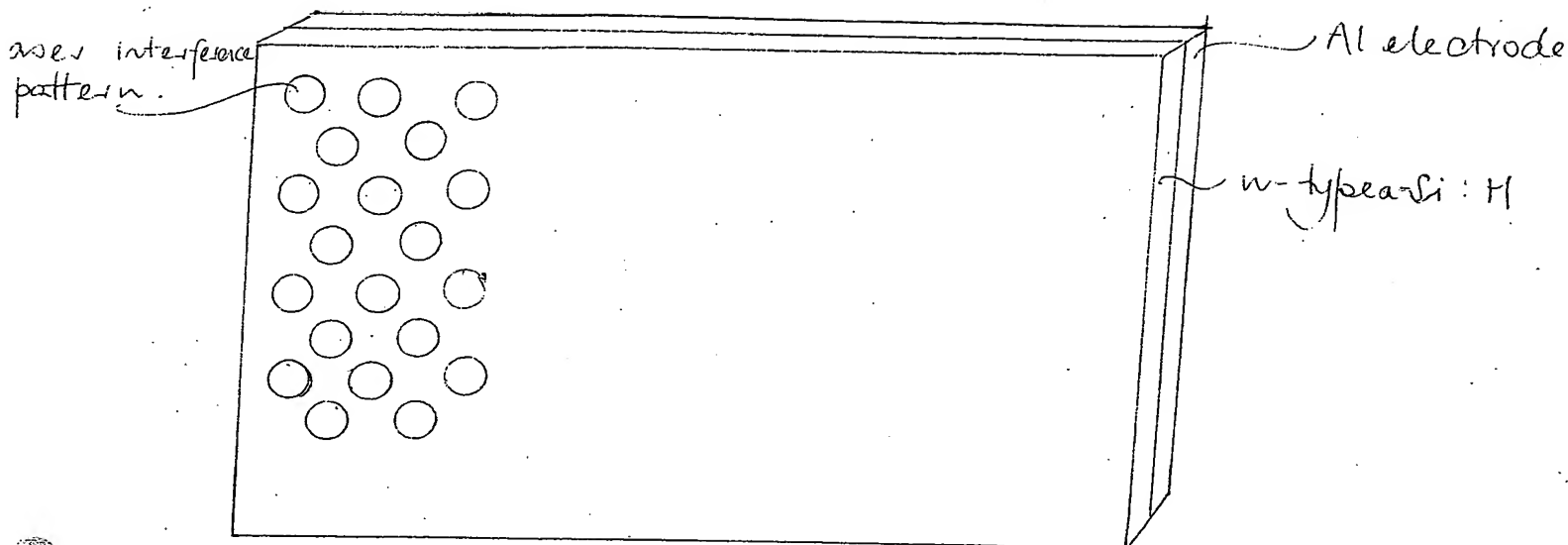


FIGURE 1.

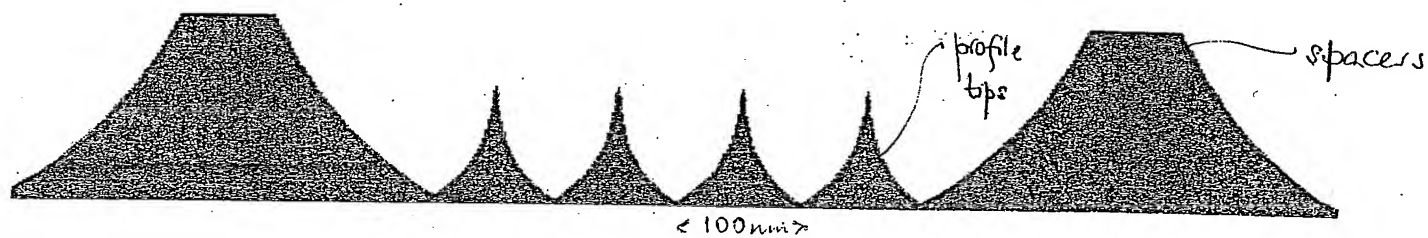


FIGURE 2

**THIS PAGE BLANK (USPTO)**



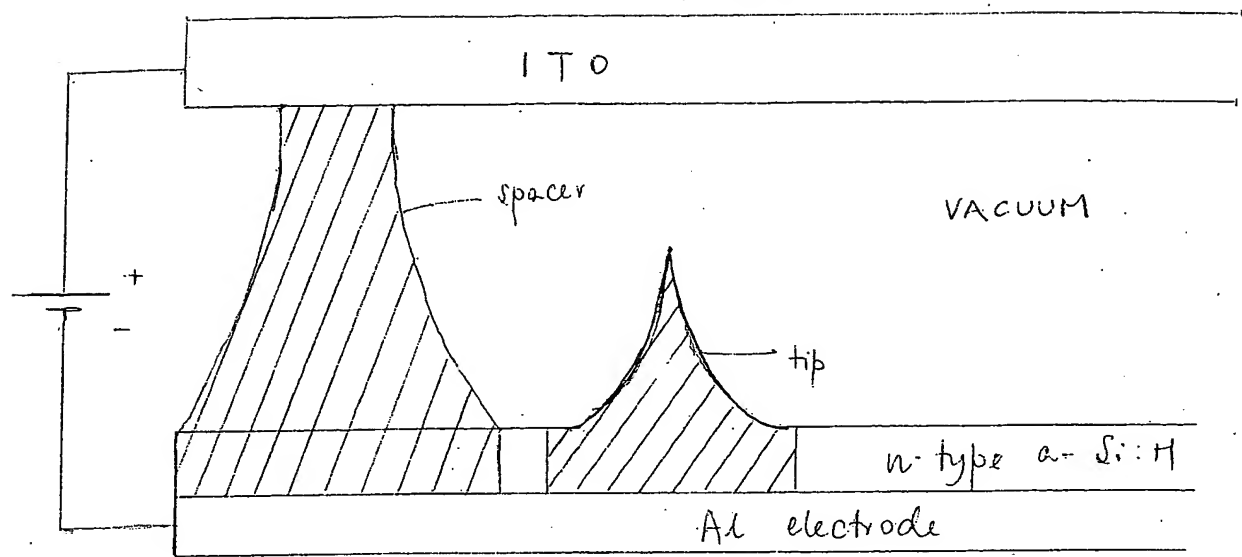


FIGURE 3

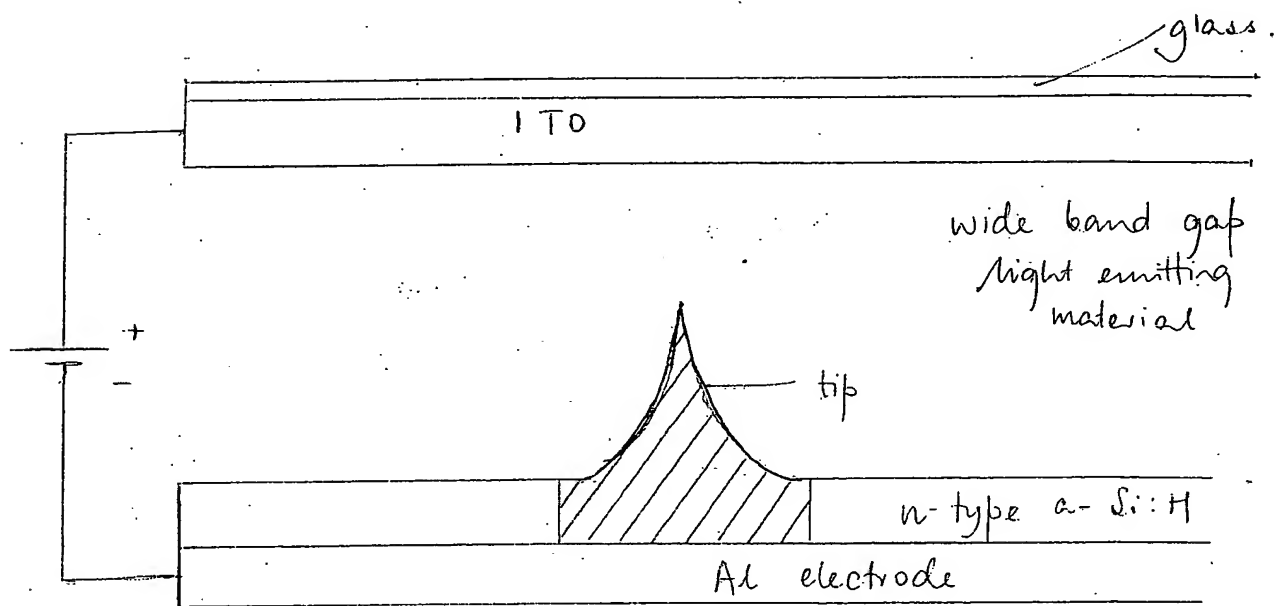
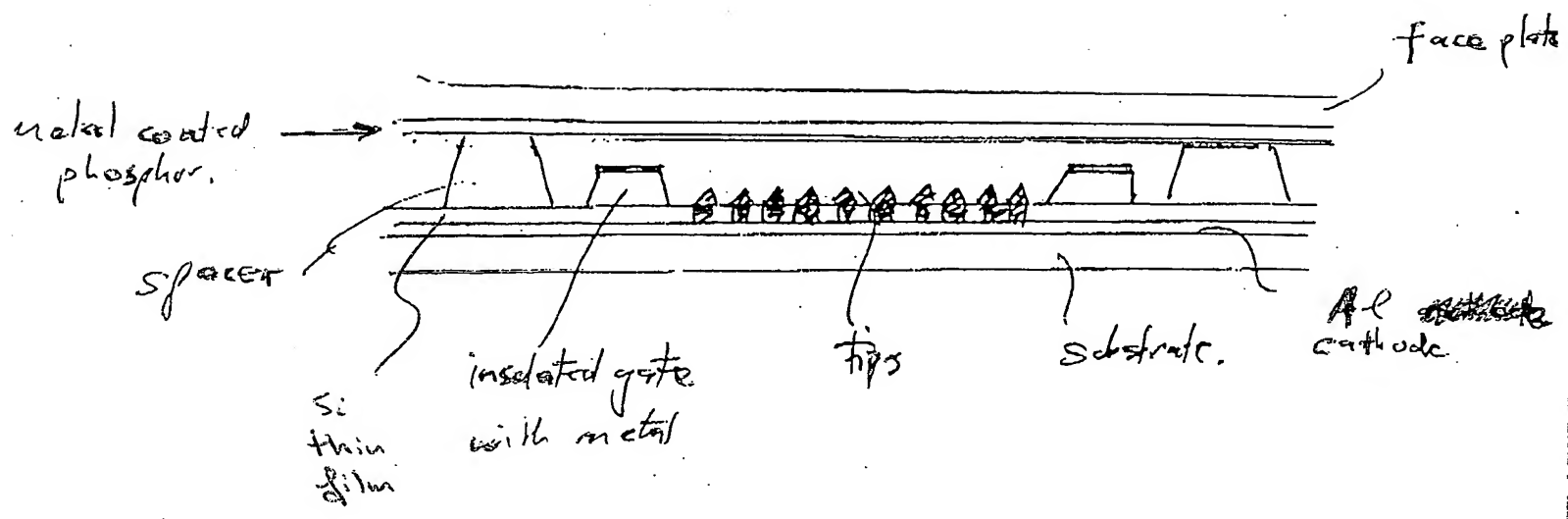


FIGURE 4.

**THIS PAGE BLANK (USPTO)**

FIGURE 5.



**THIS PAGE BLANK (USPTO)**